

GEOPHYSICAL MODEL OF CARBONATITES

COX AND SINGER MODEL NO. 10

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Geophysically related models-No. 12,
Diamond pipes; No. 29b, Olympic Dam

A. Geologic Setting

•Alkaline volcanic and sub-volcanic complexes emplaced along major zones of crustal weakness within continental, commonly Precambrian, crust (Garson, 1984).

ŽSyenite and carbonate magmas emplaced as intrusions or ring dikes, cone sheets, dikes and plugs within complex alkaline volcanic centers. Often associated with mafic and ultramafic units.

ŽCommodities include REE, apatite, magnetite, Nb, Cu, Th, U, Zr, Ti, Ni, Sr, V, fluorite, lime, and vermiculite.

B. Geologic Environment Definition

Regional magnetic, gravity, Radioelement, and remote sensing surveys may identify deep-seated fault systems, expressed as lineaments, within stable continental crust. The East African Rift, and St. Lawrence River fault system are examples (Rae, 1986; Paarma, and Talvitie, 1972).

Individual intrusive or volcanic centers show as circular to elliptical bodies in remote sensing images, and on magnetic, gravity, and Radioelement maps. On magnetic, gravity, and Radioelement maps the centers typically show as large amplitude, very complex highs, reflecting the variety of lithologies and alteration effects present. Fenitization of country rock up to 1-2 km from intrusive, is often expressed as a high-potassium halo. Phosphate and potassium enrichment in complexes can be expressed in remote sensing images by enhanced vegetation (Cole, 1982; Dawson, 1974; Ramberg, 1973; Saterly, 1970; Vorob'yev, and others, 1977).

C. Deposit Definition

Geophysical expression is highly variable dependent on the commodity, carbonatite type, extent of post-emplacment alteration, and adjacent lithologies both within the alkaline complex and of the host rock. No general rules can be given. In some cases there can be direct expression as for magnetite, niobium, uranium, and apatite mineralization expressed as magnetic or Radioelement highs. In other cases magnetic, gravity, and radioelement data are used to define individual lithologies or structures. Ground geophysics appears to have had little use in direct deposit exploration. This probably reflects the variety of commodities, and lithologies present, rather than any inherent problem with methods. In some cases electrical methods should be relevant to deposit definition, such as where hydrothermal alteration is present giving lower resistivity. Where magnetite and disseminated sulfides are present, then IP methods would be useful (Gold and others, 1967; Secher, and Thorning, 1982).

D. Size and Shape of	Shape	Average Size/Range
Alkaline center	cylinder or cone, oval to circular in cross section	<10 km diam.
Deposit	highly variable, may be tabular, cylindrical or irregular	$21 \times 10^6 / 5.7 \times 10^6 - 7999 \times 10^6 \text{ m}^3$
Alteration haloe	irregular, about deposit concentric to alkaline center	Fenitization may extend 2 km beyond alkaline center ^(2,20)

E.	Physical Properties (units)	Deposit	Alteration	Alkaline Complex	Host
		Calcitic, dolomitic or ankeritic carbonatites	Fenitization	Intrusive/volcanic center, often with mafic and ultramafic units	Continental crust
1.	Density (gm/cc)	2.79-3.41 ⁽⁵⁾	?	2.79-3.41 ⁽⁵⁾	*
2.	Porosity	variable	low?	variable	*
3.	Susceptibility	highly variable	medium < volcanic complex	variable, high on average	*
4.	Remanence	variable, gen. low	?	variable,	*
5.	Resistivity	high in massive units? medium in breccia?	?	medium to high, low cap in tropics	*
6.	IP Effect	medium?, variable 1-2% sulfide ⁽²⁰⁾ + magnetite give target	low-medium?	highly variable, reflects magnetite and disseminated sulfide distribution	*
7.	Seismic Velocity	medium-high?	high?	high?	*
8.	Radioelements				
	K (%)	highly variable 0-10	high, generally > background	high to very high 3-10x background ^(1,18) internally-highly variable	*
	U (ppm)	highly variable to 100's ⁽¹³⁾	low to medium?	"	*
	Th (ppm)	"	"	"	*
9.	Other				
	heat-flow	?	?	may be double regional due to Radioelement content	*

F. Remote Sensing Characteristics

Visible and near IR--Lineaments reflecting major zones of crustal weakness (Garson, 1984); arcuate patterns reflecting volcanic centers (Theilen-Willige, 1981), radial or annular drainage patterns. Enhanced vegetation over K and P-rich carbonatites (Cole, 1982). Spectral identification of CO₂, REE, and ferrous iron in combination unique to carbonatites (Rowan and others, 1986). The close spatial association of carbonate and alkalic rocks may be indicative.

Thermal IR--Airborne thermal imaging can identify carbonatite complex reflected in variation of fracture pattern and residual soils (Talvitie and

others, 1981). The paucity of quartz and dominant feldspar and mafic minerals may be identifiable.

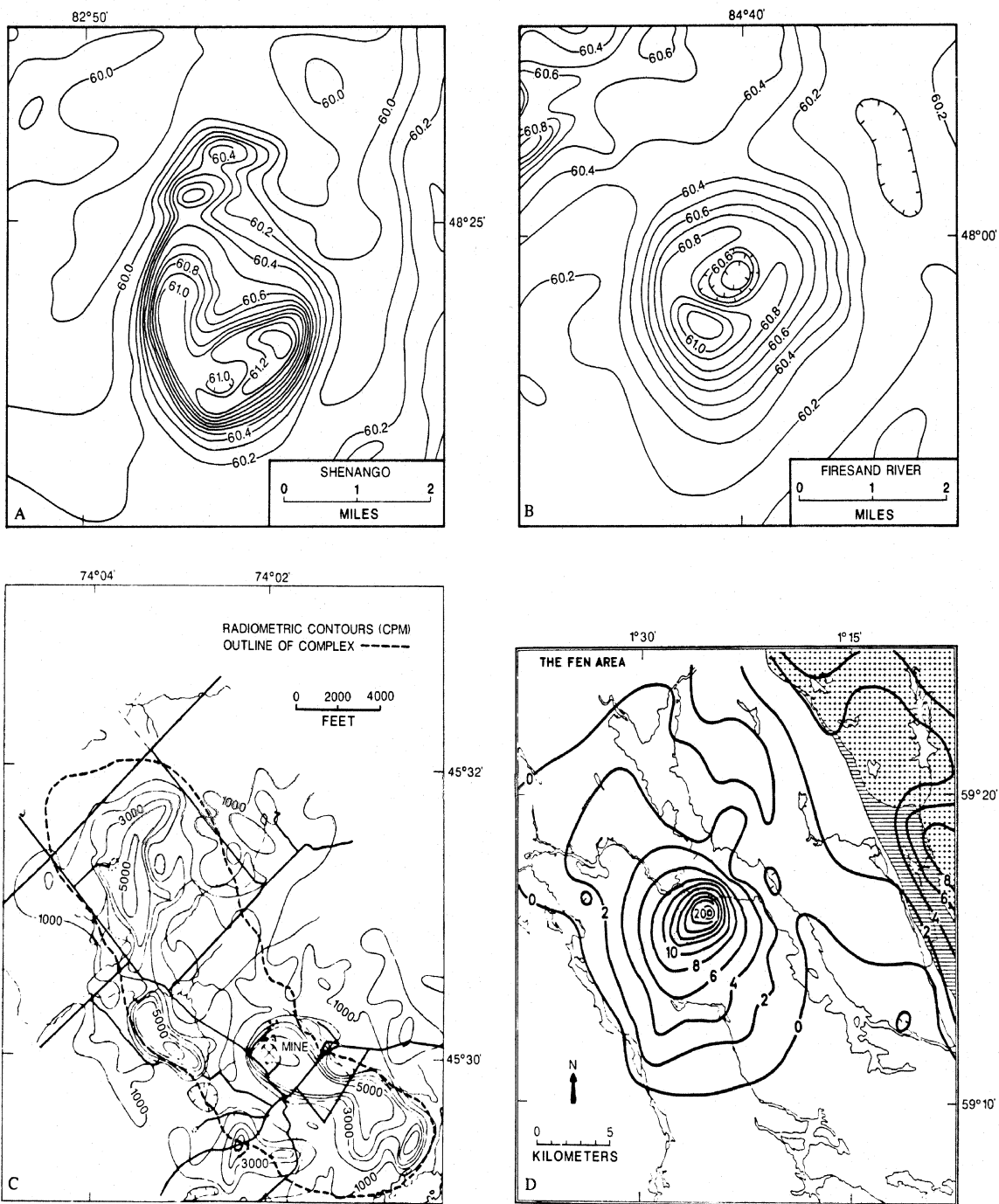
G. Comments

High density mafic and carbonate rock units generally produce a gravity anomaly of a few to 10's of mgals over alkaline complex. Magnetite in complexes can exceed 50% in some carbonatites, and is often Ti-rich. There is very little public literature relating to electrical or seismic methods applied to these deposits. However, the presence of magnetite, and commonly 1-2% disseminated sulfide (Stockford, 1972) in many deposits suggests that IP could be a useful tool. No IP surveys are known in such deposits. In tropical regions the weathering of mafic units within an alkaline complex should produce a low resistivity cap (Palacky, 1986) detectable by airborne EM techniques. Most Radioelement literature does not give results from a calibrated system, thus providing few quantitative estimates. In tropical regions potassium and especially uranium will be leached from the surface, but thorium can be concentrated (Issler, 1976). In these regions thorium provides the best radioelement indicator.

H. References

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Figures A and B. Aeromagnetic maps of the Shenango and Firesand River carbonatite complexes, Ontario, Canada, adapted from Satterly (1970). The magnetic features are about three miles across. Note the central low in the Firesand River map that Satterly (1970) reports is seen in simple carbonatite complexes. C. A total-count airborne gamma-ray map of the Oka complex, Quebec, Canada, adapted from Gold and others (1966). Areas of high counts are 4 to 5 times background. D. Residual gravity map of the Fen complex, Norway, adapted from Ramberg (1973). The 23 mgal-anomaly can be modeled by a 15 km high vertical cylinder having a density contrast of 0.48 grams per cubic centimeter.